Capacitance, C

A capacitor is two metal plates with a space between them that is non-conducting.

When a capacitor is connected to a voltage source, charge builds up. The amount of charge is determined by the size of the plates, the distance between the plates and the material in the space between them.

$C = \varepsilon A/d$

C is capacitance in Farads, F = C/V
A is the area of the smallest of the metal plates in m^2 (not added up)
d is the distance between the plates in m
ε is permittivity of the material between the plates.
for a vacuum, $\varepsilon_o = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$

The charge build up on the plates is related to the voltage
V= energy/q
W=Fd
E = V/d

C = q/V

eg. A capacitor is built using a 2.0 cm^2 sheet of copper 3.0 mm apart. Determine

a) the capacitance if the spacing is air

$C = \varepsilon A/d$

= 8.85E-12x(0.0002)/0.003=0.0

5.9×10^{-13}F = 0.59 pF

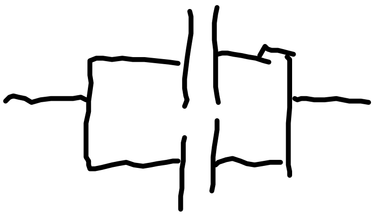
$C^2N^{-1}m^{-2} \times m^2/m \quad C^2/Nm = C^2/J = C/V$

a) the charge on the capacitor if it is connected to a 6.0V battery

q=CV = 0.59x6=3.54 pC

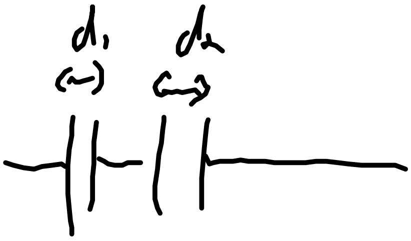
a) If you put 2 capacitors in series or in parallel, how would that influence the total capacitance?

$$C = \frac{\varepsilon A}{d}$$



$C = C_1 + C_2$ in parallel

Hecht p592-



$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$ Series

$$R = \rho \frac{L}{A}$$

A

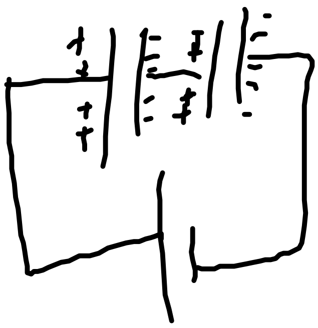
- if they are in parallel $C = C_1 + C_2$

$C = 2C_1$

$C = 1.18\ pF$

- if they are in series $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$

$\frac{1}{C_T} = \frac{1}{0.59pF} + \frac{1}{0.59pF}$



$C_T = 0.295\ pF$

$q = q_0 e^{-\frac{t}{\tau}}$

$\tau = RC$

↑ resistance of the circuit

t is the time for the charge to build up or discharge on/off the capacitor.

eg. you connect a 0.59pF capacitor to a 4.0Ω resistor and a 6.0V battery. Determine

a) the maximum charge on the capacitor?

C=q/V q=CV = 0.59x6=3.54 pC

a) the time for the capacitor to be halfway charged.

$q/q_o = 1/2 = e^{-t/\tau}$

q_o is maximum charge

q is the charge at time t

τ=RC = 4x0.59=2.36 x 10^{-12} ΩF

ln (1/2) = -0.693147180559945 =-t/2.3x10^{-12}

t = 0.693147180559945x2.3=

1.594238515287874

1.59ps

a) what is the charge at two half-lives?

t= 2x1.59=3.18

$q = q_o\, e^{-t/\tau}$

= 3.54 pC $e^{-3.18ps\ /2.36\Omega pF}$

3.54x2.718^(-3.18/2.36)=0.9202

0.92pC

a) how much energy is stored on the capacitor?

V = energy/charge

energy =Vq

C=q/V

q=CV

energy =V^2C wrong!

the charge builds up over time

energy = integral of the buildup

energy = 1/2CV^2 (the field and therefore the potential builds up linearly with charge, so the area under the V-q graph is the area of a triangle = energy)

energy stored in a capacitor = 1/2 CV^2

= 0.5x0.59x6x6=10.62 = 11pJ

Hecht p610-614
49, 67, 81, 87, 97, 104

Physics Olympics, Saturday March 10th
contests: AAPT April 6th block 2-1 ($5)
CAP April 11th 9-12 ($2) (blocks 1-4, 1-3)